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Effect of Irrigation Scheduling, Type of Nutrient Solution and Plant Density on Production and Quality of Strawberry Grown on Rooftops

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ABSTRACT

Strawberry is considered as one of high value vegetable crops. Produce strawberry from rooftops gardens can help in the availability of this crop fresh for consumers. But it was important to determine the suitable conditions for producing strawberry on rooftops. In this context, an experiment has been conducted in the rooftop garden of Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Dokki, Giza, during seasons of 2012/2013 and 2013/2014 to study the effect of irrigation scheduling, type of the nutrient solution and plant density on the production and quality of strawberry grown on rooftops. Fresh strawberry transplants cv. Festival have been used in this experiment. Three factors have been tested in this experiment in relation to strawberry production and quality; irrigation scheduling (15min each 2 hours and 15min each 3 hours), type of the nutrient solution (inorganic nutrient solution and compost tea) and plant density (20 plants per m^2 and 30 plants per m^2). Different measurements have been recorded during the experimental time such as: number of leaves, chlorophyll content in leaves, yield per plant, yield per m^2, mean fruit weight, vitamin C content in fruits, total soluble solids (TSS) percentage in fruits and (nitrogen, phosphorus, potassium) percentages in leaves. Results indicated that, concerning the effect of irrigation scheduling: strawberry plants irrigated for 15min each 2 hours recorded higher values than those irrigated for 15min each 3 hours regarding number of leaves, yield per plant, yield per m^2, mean fruit weight, vitamin C content in fruit. Concerning the effect of type of nutrient solution: using inorganic nutrient solution recorded higher values than using compost tea regarding number of leaves, chlorophyll content in leaves, yield per plant, yield per m^2, mean fruit weight and percentages of (nitrogen, phosphorus, potassium) in leaves. Nevertheless, strawberry plants irrigated with compost tea recorded higher TSS% in fruits than those irrigated with inorganic nutrient solution. Concerning the effect of plant density: cultivating 20 plants per m^2 recorded higher values than cultivating 30 plants per m^2 regarding chlorophyll content in leaves, yield per plant, mean fruit weight, vitamin C content in fruit, TSS% and percentages of (nitrogen, phosphorus, potassium) in strawberry leaves. On the contrary, even yield per plant was lower in case of cultivating 30 plants per m^2 than 20 plants per m^2 but the yield per m^2 was higher under condition of this high density.

Key words: Strawberry, irrigation scheduling, inorganic nutrient solution, compost tea, plant density, rooftops gardens.

Introduction

Over half of the world's population now lives in urban areas. As the rate of urbanization increases over time, the food production sites should be increasingly located near main consumption centers. Consequently, urban agriculture is gaining relevance all over the world (Orsini *et al*. 2013) and it is important to devise new methods and strategies to ensure the food supply and food security of those who live in urban areas (Tixier and de Bon, 2006). Moreover, roof gardens contribute positively to make cities more livable. Roof gardens can also provide farmland for local vegetable and food production. By setting up edible rooftops gardens it is possible to promote more useful and meaningful functions for the green roofs (Luckett, 2009). For that much attention must be given to vegetable production from rooftops. On the other hand, Strawberry is considered as one of high value favourable crops worldwide. It has a unique, highly desirable taste and flavour (Sturm *et al*., 2003). It is a rich source of vitamins and minerals with delicate flavours (Sharma, 2002).

Irrigation scheduling is one of the main factors affecting growth and production of strawberries; Simonne and Dukes, (2009) reported that poor timing or insufficient irrigation could resulting in crop

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stress and reduced yield, whereas excessive watering may diminish yield and quality and increase the risk of nutrient leaching. Moreover, Hoberg *et al*., (2002) reported that there is a significant effect of suitable irrigation on strawberry flavour. The development of irrigation technologies provides opportunities to improve water use efficiency, and these allow to provide exact amounts of water at the right times to meet crop water requirements (Smith and Baillie, 2009).

The fertilizers containing the nutrients to be supplied to the crop are dissolved in the appropriate concentration in the irrigation water and the resultant solution is referred to as "nutrient solution (Savvas *et al.,* 2013). On the other hand, using compost tea as a source for plant nutrients instead of mineral or inorganic nutrient solution could be a good step in producing safe agricultural products free of chemicals and pesticides. (Buchanan and Gliessman, 1991; Paulin and O'Malley, 2008; Litterick and Wood, 2009) reported that composting has been defined as a biological process through which microorganisms convert organic materials into useful end products. The solid particulate products of composting, which are extracted during the maturation and curing phase are referred to as compost. Compost can be defined as organic fertilizer produced as a result of decomposition of a wide variety of crop wastes or animal wastes or other wastes (Roy *et al*., 2006). Compost tea is a liquid extract made by steeping compost in water using a variety of preparation methods. The term compost tea used interchangeably with "watery fermented compost extracts", "organic tea" and "compost leachate" to define water based compost extract (Scheuerell and Mahaffee, 2002). The fermentation process refers to the process of steeping compost in water at a constant temperature and for a defined period of time whereby nutrients and microorganisms from the compost source are extracted (Scheuerell and Mahaffee, 2006). Compost tea can be used as a soil organic matter builder, a disease suppressant or nutrients source for plants (Ingham, 2002).

Determine the suitable planting density consider an important issue in strawberry production on rooftops. Petersen, (1998) reported that planting density plays an important role in achieving high productivity per unit area. Planting density also greatly influence production and fruit quality of strawberry plants that are grown from cuttings. Improper selection of plant population density limits the productivity of strawberry (Jensen, 1997).

For that, the aim of this experiment was to study the effect of irrigation scheduling, type of nutrient solution and plant density on production and quality of strawberry grown on rooftops.

Materials and Methods

An experiment has been conducted in the rooftop garden of Central Laboratory for Agricultural Climate, Agricultural Research Center, Ministry of Agriculture and Land Reclamation, Dokki, Giza, during seasons of 2012/2013 and 2013/2014 to study the effect of irrigation scheduling, type of the nutrient solution and plant density on the production and quality of strawberry grown on rooftops.

Fresh bare root strawberry *(Fragaria x ananassa)* transplants cv. Festival were used in this experiment. Transplants were cultivated into beds system in the middle of September 2012 and replicated in the same time in 2013.

The beds system consisted of wooden table (100cm length, 100cm width, and 10cm depth) and height of table legs was 60cm from rooftop floor. Each table laid with black polyethylene sheets 0.5 mm in thickness and equipped with drainage tube in one side, also equipped with one bucket under each table to collect the excess diluted nutrient solution. The entire part of the wooden table was filled with 100 liters of perlite.

Three factors have been tested in this experiment in relation to strawberry production and quality. The tested factors were as follow:

Factor (A): irrigation scheduling:

- 15min each 2 hours (IR-1).
- 15min each 3 hours (IR-2).

Factor (B): type of nutrient solution:

- Inorganic nutrient solution (IN-S).
- Compost tea (CT-S).

Factor (C): plant density:

- 20 plants per m^2 (PD-1).
- 30 plants per m^2 (PD-2).

The inorganic nutrient solution used in this experiment was the nutrient solution described by El-Behairy, (1994). On the other hand, the compost tea was formed from steeping the compost in suitable amount of water (1compost: 3water v/v) and left it for one week then used the formed solution as compost tea. Data in table (1) illustrates the chemical analysis of the compost that used in this experiment. The

electrical conductivity (EC) adjusted at the range of 2 -2.5 m.mhos^2 during the experimental time. Digital EC meter was used to adjust the EC to the required levels.

Table 1: Chemical analysis of the compost

Macro nutrients (%)					Micro nutrients (ppm)			
N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
0.980	0.451	0.770	1.46	0.500	5690.00	118.20	56.00	19.80

Drip irrigation system have been used to deliver the diluted nutrient solutions (inorganic nutrient solution or compost tea) to each plant then a slope about 1% have been made for collecting the excess drained diluted nutrient solution and return it back to the catchment bucket using the drainage tube. The irrigation timing and schedules was managed using timer.

Different measurements have been recorded during the experimental time such as: number of leaves, chlorophyll content in leaves (SPAD), yield per plant (g), yield per m^2(kg), mean fruit weight (g), vitamin C was determined in fruit juice as described in A.O.A.C, (1990) and expressed as mg/100g, total soluble solids (TSS) in fruits were recorded as (%) using hand refractometer (Atago No.1, 0-32 Brix, Japan), and percentages of (nitrogen, phosphorus, potassium) in leaves.

The experiment was arranged in split-split plot design with three replicates. The irrigation scheduling was arranged in main plots, type of nutrient solution was arranged in sub plots and finally plant density was arranged in sub-sub plots. The collected data were analyzed using ANOVA statistical analysis as described by Snedicor and Cochran, (1980) and the least significant difference (LSD) at a probability level of 5% was used in comparison among means.

Results

Number of leaves:

Data in table (2) presents the effect of irrigation scheduling, type of nutrient solution and plant density on number of leaves per plant.

Regarding the effect of irrigation scheduling, data collected from both seasons illustrated that IR-1 recorded higher number of leaves than IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons indicated that plants irrigated with inorganic nutrient solution recorded higher number of leaves than those irrigated with compost tea.

Regarding the effect of plant density, data collected from the first season illustrated that there was no significant difference between the two tested plant densities. Nevertheless, data collected from the second season illustrated that PD-1 recorded higher number of leaves than PD-2.

Regarding interactions, data illustrated that in both seasons there were no significant differences among all interactions.

Chlorophyll content in leaves:

Data in table (3) presents the effect of irrigation scheduling, type of nutrient solution and plant density on chlorophyll content in leaves (SPAD).

Regarding the effect of irrigation scheduling, data collected from both seasons illustrated that there was no significant difference between IR-1 and IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons illustrated that plants irrigated with inorganic nutrient solution recorded higher chlorophyll content in leaves than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons illustrated that PD-1 recorded higher chlorophyll content in leaves than PD-2.

Data also illustrated that in both seasons there were no significant differences among interactions except the interaction between type of nutrient solution and plant density.

Regarding interaction between type of nutrient solution and plant density, data collected from the first season indicated that interaction between IN-S and PD-1 (IN-S+PD-1) recorded the highest chlorophyll content, while interaction between CT-S and PD-2 (CT-S+PD-2) recorded the lowest chlorophyll content. Moreover, differences among interactions were significant except between (IN-S+PD-1) and (IN-S+PD-2) was not significant. Similar trends were observed in the second season except that all differences among interactions were significant.

Table 2: Effect of irrigation scheduling, type of nutrient solution and plant density on number of leaves of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	10.55	10.46	10.50
IR-1	CT-S	9.09	8.73	8.91
	Mean	9.82	9.59	9.71
	IN-S	9.42	8.94	9.18
IR-2	CT-S	8.60	8.14	8.37
	Mean	9.01	8.54	8.78
Solution * Plant density				
	IN-S	9.98	9.70	9.84
	CT-S	8.84	8.44	8.64
Plant density mean		9.41	9.07	
Second season				
	IN-S	11.97	10.08	11.03
IR-1	CT-S	9.28	7.58	8.43
	Mean	10.63	8.83	9.73
	IN-S	9.91	8.79	9.35
IR-2	CT-S	7.96	6.80	7.38
	Mean	8.94	7.79	8.36
Solution * Plant density				
	IN-S	10.94	9.44	10.19
	CT-S	8.62	7.19	7.91
Plant density mean		9.78	8.31	
L.S.D at 5%				
First season			Second season	
A	0.38		A	0.75
B	0.84		B	0.43
C	N.S		C	0.31
A.B	N.S		A.B	N.S
A.C	N.S		A.C	N.S
B.C	N.S		B.C	N.S
ABC	N.S		ABC	N.S

Table 3: Effect of irrigation scheduling, type of nutrient solution and plant density on chlorophyll content in leaves (SPAD) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	38.33	40.67	39.50
IR-1	CT-S	33.00	25.00	29.00
	Mean	35.67	32.83	34.25
	IN-S	42.00	40.33	41.17
IR-2	CT-S	34.00	26.00	30.00
	Mean	38.00	33.17	35.58
Solution * Plant density				
	IN-S	40.17	40.00	40.08
	CT-S	33.50	25.50	29.50
Plant density mean		36.83	32.75	
Second season				
	IN-S	43.33	39.00	41.17
IR-1	CT-S	30.00	20.67	25.33
	Mean	36.67	29.83	33.25
	IN-S	45.33	43.33	44.33
IR-2	CT-S	28.67	21.00	24.83
	Mean	37.00	32.17	34.58
Solution * Plant density				
	IN-S	44.33	41.27	42.75
	CT-S	29.33	20.83	25.08
Plant density mean		36.81	31.00	
L.S.D at 5%				
First season			Second season	
A	N.S		A	N.S
B	2.54		B	4.3
C	1.49		C	1.42
A.B	N.S		A.B	N.S
A.C	N.S		A.C	N.S
B.C	2.10		B.C	2.01
ABC	N.S		ABC	N.S

Yield per plant:

Data in table (4) presents the effect of irrigation scheduling, type of nutrient solution and plant density on yield per plant (g).

Regarding the effect of irrigation scheduling, data collected from both seasons showed that IR-1 recorded higher yield per plant than IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons illustrated that plants irrigated with inorganic nutrient solution recorded higher yield per plant than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons showed that PD-1 recorded higher yield per plant than PD-2.

Regarding interaction between irrigation scheduling and type of nutrient solution, in the first season, the highest yield per plant was recorded in (IR-1+ IN-S) while the lowest yield value was recorded by (IR-2+ CT-S). Differences among interactions were significant. The same trend was observed in the second season.

Regarding interaction between irrigation scheduling and plant density, data collected from both seasons indicated that the highest yield per plant was recorded in (IR-1+ PD-1), while the lowest yield value was recorded in (IR-2+ PD-2). Differences among interactions were significant.

Regarding interaction between type of nutrient solution and plant density, data collected from both seasons indicated that (IN-S+PD-1) recorded the highest yield per plant, while (CT-S+PD-2) recorded the lowest values. Moreover, differences among all interactions were significant.

Regarding interaction between irrigation scheduling, type of nutrient solution and plant density, there were no significant differences among interactions in both seasons.

Yield per m^2:

Data in table (5) presents the effect of irrigation scheduling, type of nutrient solution and plant density on yield per m^2 (kg).

Regarding the effect of irrigation scheduling, data collected from both seasons indicated that IR-1 recorded higher yield per m^2 than IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons illustrated that plants irrigated with inorganic nutrient solution recorded higher values regarding yield per m^2 than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons illustrated that increasing plant density increased yield per m^2.

Regarding interaction between irrigation scheduling and type of nutrient solution, data collected from both seasons indicated that the highest yield per m^2 values were recorded in (IR-1+ IN-S) while the lowest values were recorded by (IR-2+ CT-S). Differences among interactions were significant.

Regarding interaction between irrigation scheduling and plant density, data collected from the first season showed that the highest yield per m^2 values were recorded in (IR-1+PD-2). On the other hand, the lowest values were recorded by (IR-2+PD-1). Moreover, data showed that difference between (IR-1+PD-1) and (IR-2+PD-1) was not significant but all other differences were significant. On contrary, data collected from the second seasons illustrated that differences among interactions were not significant

Regarding interaction between type of nutrient solution and plant density, data collected from the first season illustrated that the highest yield per m^2 values were recorded in (IN-S+ PD-2). On contrary, (CT-S +PD-1) recorded the lowest values. Data also illustrated that differences among interactions were significant. The same trend was observed in the second season.

Regarding interaction between irrigation scheduling, type of nutrient solution and plant density, data collected from both season illustrated that there were no significant differences among interactions.

Table 4: Effect of irrigation scheduling, type of nutrient solution and plant density on yield per plant (g) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	660.66	555.83	608.25
IR-1	CT-S	471.25	381.88	426.56
	Mean	565.95	468.85	517.40
	IN-S	661.95	503.78	582.87
IR-2	CT-S	441.90	317.61	379.75
	Mean	551.92	410.69	481.31
Solution * Plant density				
	IN-S	661.31	529.81	595.56
	CT-S	456.57	349.74	403.16
Plant density mean		558.94	439.77	
Second season				
	IN-S	622.89	578.16	600.53
IR-1	CT-S	528.27	389.90	459.08
	Mean	575.58	484.03	529.81
	IN-S	522.87	498.44	510.65
IR-2	CT-S	492.80	358.87	425.83
	Mean	507.83	428.65	468.24
Solution * Plant density				
	IN-S	572.88	538.30	555.59
	CT-S	510.53	374.38	442.46
Plant density mean		541.71	456.34	
L.S.D at 5%				
First season			Second season	
A	6.59		A	12.84
B	2.72		B	8.20
C	9.69		C	4.90
A.B	3.84		A.B	11.59
A.C	13.71		A.C	7.05
B.C	13.01		B.C	6.93
ABC	N.S		ABC	N.S

Table 5: Effect of irrigation scheduling, type of nutrient solution and plant density on yield per m2 (kg) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	13.21	16.67	14.94
IR-1	CT-S	9.42	11.46	10.44
	Mean	11.32	14.07	12.69
	IN-S	13.24	15.11	14.18
IR-2	CT-S	8.84	9.53	9.18
	Mean	11.04	12.32	11.68
Solution * Plant density				
	IN-S	13.23	15.89	14.56
	CT-S	9.13	10.49	9.81
Plant density mean		11.18	13.19	
Second season				
	IN-S	12.46	17.34	14.90
IR-1	CT-S	10.57	11.70	11.13
	Mean	11.51	14.52	13.02
	IN-S	10.46	14.95	12.71
IR-2	CT-S	9.86	10.77	10.31
	Mean	10.16	12.86	11.51
Solution * Plant density				
	IN-S	11.46	16.15	13.80
	CT-S	10.21	11.23	10.72
Plant density mean		10.83	13.69	
L.S.D at 5%				
First season			Second season	
A	0.30		A	0.29
B	0.07		B	0.23
C	0.27		C	0.13
A.B	0.09		A.B	0.32
A.C	0.38		A.C	N.S
B.C	0.35		B.C	0.19
ABC	N.S		ABC	N.S

Mean fruit weight:

Data in table (6) presents the effect of irrigation scheduling, type of nutrient solution and plant density on mean fruit weight (g).

Regarding the effect of irrigation scheduling, data collected from both seasons showed that IR-1 recorded higher values for mean fruit weight than IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons indicated that plants irrigated with inorganic nutrient solution recorded higher mean fruit weight values than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons illustrated that increasing plant density decreased mean fruit weight values.

Regarding interactions, Data indicated that there were no significant differences among interactions except regarding the interaction between type of nutrient solution and plant density in the second season only. The collected data indicated that the highest mean fruit weight values were obtained from (IN-S+ PD-1). On contrary, (CT-S +PD-2) recorded the lowest values.

Table 6: Effect of irrigation scheduling, type of nutrient solution and plant density on mean fruit weight (g) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
IR-1	IN-S	19.07	15.55	17.31
	CT-S	14.10	12.86	13.48
	Mean	16.59	14.20	15.39
IR-2	IN-S	17.04	15.31	16.17
	CT-S	14.32	12.14	13.23
	Mean	15.68	13.73	14.70
Solution * Plant density				
	IN-S	18.05	15.43	16.74
	CT-S	14.21	12.50	13.36
Plant density mean		16.13	13.96	
Second season				
IR-1	IN-S	18.76	16.87	17.81
	CT-S	15.02	11.44	13.23
	Mean	16.89	14.16	15.52
IR-2	IN-S	16.45	15.00	15.73
	CT-S	13.88	10.57	12.23
	Mean	15.17	12.79	13.98
Solution * Plant density				
	IN-S	17.61	15.94	16.77
	CT-S	14.45	11.01	12.73
Plant density mean		16.03	13.47	

L.S.D at 5%			
First season		Second season	
A	0.17	A	0.97
B	0.62	B	1.26
C	0.57	C	0.71
A.B	N.S	A.B	N.S
A.C	N.S	A.C	N.S
B.C	N.S	B.C	1.01
ABC	N.S	ABC	N.S

Vitamin C content in fruits:

Data in table (7) presents the effect of irrigation scheduling, type of nutrient solution and plant density on vitamin C content in fruits (mg/100g).

Regarding the effect of irrigation scheduling, data collected from the first season illustrated that IR-1 recorded higher vitamin C content than IR-2. The same trend was observed in the second season.

Regarding the effect of type of nutrient solution, data collected from both seasons indicated that there was no significant difference between inorganic nutrient solution and compost tea regarding vitamin C content in fruits.

Regarding the effect of plant density, data collected from both seasons illustrated that PD-1 recorded higher vitamin C content in fruits than PD-2.

Regarding interactions, Data indicated that there were no significant differences among interactions except the interaction between irrigation scheduling and type of nutrient solution, also interaction between type of nutrient solution and plant density.

Regarding interaction between irrigation scheduling and type of nutrient solution, data collected from the first season illustrated that the (IR-1+IN-S) recorded the highest vitamin C content while (IR-2+ IN-S) recorded the lowest value for vitamin C. data also indicated that differences among interactions were significant. Similar trend was observed in the second season except that the difference between (IR-1+CT-S) and (IR-2+CT-S) was not significant.

Regarding interaction between type of nutrient solution and plant density, data collected from the first season indicated that the highest vitamin C content was recorded in (IN-S+ PD-1) while the lowest value for vitamin C was recorded in (IN-S+ PD-2). Moreover, there was no significant difference between (IN-S+ PD-1) and (CT-S+ PD-1) or between (CT-S+ PD-1) and (CT-S+ PD-2), other differences were significant. On contrary, data collected from the second season showed that there were no significant differences among interactions

Table 7: Effect of irrigation scheduling, type of nutrient solution and plant density on vitamin C content in fruits (mg/100g) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
		First season		
	IN-S	89.30	84.10	86.7
IR-1	CT-S	72.80	71.10	72.0
	Mean	81.05	77.60	79.33
	IN-S	62.97	52.43	57.70
IR-2	CT-S	76.27	74.31	75.29
	Mean	69.62	63.37	66.49
		Solution * Plant density		
	IN-S	76.14	68.26	72.20
	CT-S	74.53	72.71	73.62
Plant density mean		75.33	70.49	
		Second season		
	IN-S	89.10	85.00	87.05
IR-1	CT-S	73.53	70.30	71.9
	Mean	81.32	77.65	79.48
	IN-S	63.67	56.67	60.17
IR-2	CT-S	74.97	71.33	73.15
	Mean	69.32	64.00	66.66
		Solution * Plant density		
	IN-S	76.38	70.83	73.61
	CT-S	74.25	70.82	72.53
Plant density mean		75.32	70.83	

L.S.D at 5%			
First season		Second season	
A	1.29	A	3.21
B	N.S	B	N.S
C	1.87	C	1.71
A.B	2.25	A.B	2.67
A.C	N.S	A.C	N.S
B.C	2.65	B.C	N.S
ABC	N.S	ABC	N.S

Total soluble solids (TSS) percentage in fruits:

Data in table (8) presents the effect of irrigation scheduling, type of nutrient solution and plant density on total soluble solids (TSS) % in fruits.

Regarding the effect of irrigation scheduling, data collected from both seasons showed that there was no significant difference between IR-1 and IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons indicated that using compost tea increased TSS% than inorganic nutrient solution.

Regarding the effect of plant density, data collected from both seasons illustrated that PD-1 recorded higher TSS% in fruits than PD-2.

Regarding interactions, Data indicated that there were no significant differences among interactions except the interaction between irrigation scheduling and plant density, also interaction between type of the nutrient solution and plant density.

Regarding interaction between irrigation scheduling and plant density, data collected from the first season indicated that differences among interactions were not significant. On contrary, data collected from the second season illustrated that (IR-2+PD-1) recorded the highest TSS% while (IR-1+PD-2) recorded the lowest TSS% in fruits. Moreover, data indicated that differences among (IR-2+PD-1) and all other interactions were significant while differences among (IR-1+PD-1), (IR-1+PD-2) and (IR-2+PD-2) were not significant.

Regarding interaction between type of nutrient solution and plant density, data collected from the first season indicated that (CT-S+PD-1) recorded the highest TSS% while (IN-S+PD-2) recorded the lowest TSS%. Moreover, differences among interactions were significant. Nevertheless, data indicated that there were no significant differences in the second seasons.

Table 8: Effect of irrigation scheduling, type of nutrient solution and plant density on total soluble solids in fruits (%) of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
		First season		
	IN-S	7.02	5.30	6.16
IR-1	CT-S	9.10	8.50	8.80
	Mean	8.06	6.90	7.48
	IN-S	7.24	5.93	6.59
IR-2	CT-S	9.07	8.57	8.82
	Mean	8.15	7.25	7.70
		Solution * Plant density		
	IN-S	7.13	5.62	6.38
	CT-S	9.08	8.53	8.81
Plant density mean		8.11	7.08	
		Second season		
	IN-S	4.83	5.13	4.98
IR-1	CT-S	9.17	8.67	8.92
	Mean	7.00	6.90	6.95
	IN-S	6.80	5.57	6.18
IR-2	CT-S	9.40	8.47	8.93
	Mean	8.10	7.02	7.56
		Solution * Plant density		
	IN-S	5.82	5.35	5.58
	CT-S	9.28	8.57	8.93
Plant density mean		7.55	6.96	
		L.S.D at 5%		
First season			Second season	
A	N.S		A	N.S
B	0.35		B	0.51
C	0.22		C	0.37
A.B	N.S		A.B	N.S
A.C	N.S		A.C	0.53
B.C	0.31		B.C	N.S
ABC	N.S		ABC	N.S

Nitrogen percentage in leaves:

Data in table (9) presents the effect of irrigation scheduling, type of nutrient solution and plant density on nitrogen % in leaves.

Regarding the effect of irrigation scheduling, data collected from both seasons showed that there was no significant difference between IR-1 and IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons illustrated that plants irrigated with inorganic nutrient solution recorded higher nitrogen % in leaves than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons illustrated that PD-1 recorded higher nitrogen % than PD-2.

Regarding interactions, Data indicated that there were no significant differences among interactions except the interaction between irrigation Scheduling and type of the nutrient solution. Regarding this interaction, data collected from the first season indicated that the highest nitrogen % was recorded in (IR-1+IN-S) while the lowest was recorded in (IR-2+ CT-S). On contrary, data collect from the second season illustrated that there were no significant differences among interactions.

Table 9: Effect of irrigation scheduling, type of nutrient solution and plant density on nitrogen % in leaves of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
IR-1	IN-S	3.89	2.80	3.35
	CT-S	2.27	2.02	2.15
	Mean	3.08	2.41	2.75
IR-2	IN-S	3.02	2.70	2.86
	CT-S	2.23	1.92	2.08
	Mean	2.63	2.31	2.47
Solution * Plant density				
	IN-S	3.46	2.75	3.10
	CT-S	2.25	1.97	2.11
Plant density mean		2.85	2.36	
Second season				
IR-1	IN-S	3.53	3.20	3.36
	CT-S	2.65	2.06	2.35
	Mean	3.09	2.63	2.86
IR-2	IN-S	3.31	2.98	3.15
	CT-S	2.45	1.60	2.03
	Mean	2.88	2.29	2.59
Solution * Plant density				
	IN-S	3.42	3.09	3.25
	CT-S	2.55	1.83	2.19
Plant density mean		2.99	2.46	
L.S.D at 5%				
First season			Second season	
A	N.S		A	N.S
B	0.23		B	0.59
C	0.35		C	0.22
A.B	0.15		A.B	N.S
A.C	N.S		A.C	N.S
B.C	N.S		B.C	N.S
ABC	N.S		ABC	N.S

Phosphorus percentage in leaves:

Data in table (10) presents the effect of irrigation scheduling, type of nutrient solution and plant density on phosphorus % in leaves.

Regarding the effect of irrigation scheduling, data collected from both seasons showed that there was no significant difference between IR-1 and IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons illustrated that plants irrigated with inorganic nutrient solution recorded higher phosphorus % in leaves than those irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons indicated that PD-1 recorded higher phosphorus % than PD-2.

Regarding interactions, Data indicated that there were no significant differences among all interactions.

Potassium percentage in leaves:

Data in table (11) presents the effect of irrigation scheduling, type of nutrient solution and plant density on potassium % in leaves.

Regarding the effect of irrigation scheduling, data collected from both seasons showed that there was no significant difference between IR-1 and IR-2.

Regarding the effect of type of nutrient solution, data collected from both seasons indicated that plants irrigated with inorganic nutrient solution recorded higher potassium % than plants irrigated with compost tea.

Regarding the effect of plant density, data collected from both seasons illustrated that PD-1 recorded higher potassium % than PD-2.

Regarding interactions, Data showed that there were no significant differences among interactions except the interaction between irrigation scheduling and type of the nutrient solution in the second season only. Regarding this interaction, data illustrated that the highest potassium % was recorded in (IR-1+IN-S) while the lowest was recorded in (IR-1+ CT-S).

Table 10: Effect of irrigation scheduling, type of nutrient solution and plant density on phosphorus % in leaves of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	0.572	0.427	0.500
IR-1	CT-S	0.307	0.232	0.270
	Mean	0.440	0.330	0.385
	IN-S	0.517	0.411	0.464
IR-2	CT-S	0.258	0.218	0.238
	Mean	0.387	0.315	0.351
Solution * Plant density				
	IN-S	0.545	0.419	0.482
	CT-S	0.282	0.225	0.254
Plant density mean		0.413	0.322	
Second season				
	IN-S	0.597	0.514	0.556
IR-1	CT-S	0.368	0.215	0.292
	Mean	0.483	0.365	0.424
	IN-S	0.552	0.462	0.507
IR-2	CT-S	0.274	0.207	0.240
	Mean	0.413	0.334	0.374
Solution * Plant density				
	IN-S	0.575	0.488	0.531
	CT-S	0.321	0.211	0.266
Plant density mean		0.448	0.349	
L.S.D at 5%				
First season			Second season	
A	N.S		A	N.S
B	0.030		B	0.043
C	0.034		C	0.031
A.B	N.S		A.B	N.S
A.C	N.S		A.C	N.S
B.C	N.S		B.C	N.S
ABC	N.S		ABC	N.S

Table 11: Effect of irrigation scheduling, type of nutrient solution and plant density on potassium % in leaves of strawberry plants grown on rooftops during seasons of 2012/2013 and 2013/2014.

Irrigation (A)	Solution (B)	Plant density (C) PD-1	PD-2	Mean
First season				
	IN-S	3.33	3.04	3.19
IR-1	CT-S	2.60	2.08	2.34
	Mean	2.96	2.56	2.76
	IN-S	3.29	2.84	3.06
IR-2	CT-S	2.36	1.99	2.18
	Mean	2.83	2.42	2.62
Solution * Plant density				
	IN-S	3.31	2.94	3.12
	CT-S	2.48	2.04	2.26
Plant density mean		2.89	2.49	
Second season				
	IN-S	3.84	3.24	3.54
IR-1	CT-S	2.34	2.11	2.23
	Mean	3.09	2.68	2.89
	IN-S	3.48	3.01	3.25
IR-2	CT-S	2.58	2.05	2.32
	Mean	3.03	2.53	2.78
Solution * Plant density				
	IN-S	3.66	3.13	3.40
	CT-S	2.46	2.08	2.27
Plant density mean		3.06	2.61	
L.S.D at 5%				
First season			Second season	
A	N.S		A	N.S
B	0.22		B	0.09
C	0.19		C	0.12
A.B	N.S		A.B	0.15
A.C	N.S		A.C	N.S
B.C	N.S		B.C	N.S
ABC	N.S		ABC	N.S

Discussion

Concerning the effect of irrigation scheduling, strawberry plants irrigated for 15min each 2 hours recorded higher values than those irrigated for 15min each 3 hours regarding number of leaves, yield per plant, yield per m^2, mean fruit weight, vitamin C content in fruit. It's clear that irrigation scheduling affected significantly on the growth, production and fruit quality of strawberry plants grown in beds system on rooftops. May be this was a result to that irrigation each 2 hours gave plants their suitable requirements of water and nutrients dissolved in it. On contrary, in case of irrigation each 3 hours; the intervals periods between irrigation times were long and plants suffer from water or nutrient shortage and this was the reason that plants irrigated each 3 hours recorded a lower values than those irrigated each 2 hours. Simonne and Dukes, (2009) mentioned that poor timing or insufficient irrigation could resulting in crop stress and reduced yield whereas excessive watering may diminish yield and increase the risk of nutrient leaching. Moreover, Kruger *et al.,* (1999) reported that the proper irrigation has a positive influence on strawberry yield, fruit size. Serrano *et al*., (1992) mentioned that correct irrigation management can improve strawberry yields as strawberry plants show large responses to water stress.

Concerning the effect of type of nutrient solution, using inorganic nutrient solution recorded higher values than using compost tea regarding number of leaves, chlorophyll content in leaves, yield per plant, yield per m^2, mean fruit weight and percentages of (nitrogen, phosphorus, potassium) in leaves. This may be a result to that compost tea alone didn't supply strawberry plants with their requirements from nutrients so this reflected negatively on plant growth and production. Scheuerell and Mahaffee, (2006) reported that compost tea works well with most soilless media and can serve as a preventive measure to suppress pathogens before they cause disease. Compost tea is not considered a fertilizer only (as it provides minimal nutrient levels) nor is it considered a fungicide or pesticide either. It enhances microbial activity in the growing medium which helps improve plant growth. Abd El-Aziz, (2003) reported that using compost tea as organic nutrient solution reduced vegetative growth of cantaloupe plants grown in nutrient film technique comparing with inorganic nutrient solution. In addition, Abou El-Hassan *et al.,* (2008) found that using inorganic nutrient solution gave higher total yield of cantaloupe under nutrient film technique conditions than compost tea as organic source of nutrient solution.

Concerning the effect of plant density, cultivating 20 plants per m^2 recorded higher values than cultivating 30 plants per m^2 regarding chlorophyll content in leaves, yield per plant, mean fruit weight, vitamin C content in fruit, TSS% and percentages of (nitrogen, phosphorus, potassium) in strawberry leaves. Tehranifar *et al*., (2007) and Paranjpe *et al*., (2008) reported that low planting density increased number of leaves per plant . Moreover, Lee *et al.,* (2002) studied the effect of using different plant densities (32, 48 and 64 plants per m^2) on growth of cut chrysanthemum. Data showed that number of flowers per plant decreased with increasing the plant density. Nevertheless the yield per plant was lower in case of cultivating 30 plants per m^2 than 20 plants per m^2 but the yield per m^2 was higher under condition of this high density. This is a result to increasing number of plants per m^2, so even the yield per plant was smaller but the high number recover the reduction in yield. De Hoog *et al.,* (2001) studied the effect of different plant densities (5, 7.5 and 10 plants per m^2) on the production and quality of roses grown in artificial root substrate. Results showed that the highest plant density gave the highest production. Also, De-Camacaro *et al.,* (2004) mentioned that in strawberry, yield per plant increased by increasing plant spacing from 20 to 30 cm (low plant density) but the highest yield per square meter were obtained at the closest spacing (high plant density).

Conclusion

From the above mentioned results it could be concluded that regarding the effect of irrigation Scheduling, strawberry plants irrigated for 15min each 2 hours recorded higher growth, production and quality values than those irrigated for 15min each 3 hours.

Regarding the effect of type of nutrient solution, using inorganic nutrient solution recorded higher growth, yield values than using compost tea. Nevertheless, strawberry plants irrigated with compost tea recorded higher TSS% in fruit than those irrigated with inorganic nutrient solution.

Regarding the effect of plant density, cultivating 20 plants per m^2 recorded higher growth, production and quality values than cultivating 30 plants per m^2. On the contrary, even yield per plant was lower in case of cultivating 30 plants per m^2 than 20 plants per m^2 but the yield per m^2 was higher under condition of this high density.

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